Phyllocarid Arthropods and Associated Biota from a Carbonaceous Black Shale in the Breathitt Formation (Pennsylvanian), Northern Kentucky

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ABSTRACT--A new species of phyllocarid crustacean, Dithyrocaris rosarius, is described from a 40-cm-thick carbonaceous black shale in the Breathitt Formation (Pennsylvanian) along Kentucky Highway 546 (AA Highway), approximately 30 km east of Vanceburg, Kentucky. The biota of this carbonaceous black shale consists of common D. rosarius, common plant fragments, and less common bivalves (Posidonia), gastropods, and brachiopods (Leiorhynchoidea and Linoproductus). Sparse trace fossils are also present. They include coprolites that contain phyllocarid? fragments; indeterminate, vermiform horizontal burrows; and Zoophycos. Beds are thinly laminated and seem to have been only rarely disturbed by bioturbation. The black shale has been previously interpreted to represent a time of maximum transgression in a transgressive-regressive marginal marine-to-marine cyclothem. However, evidence for a deep marine origin of the carbonaceous black shale is ambiguous. Thinly laminated black shales with sparse bioturbation and undisturbed coprolites indicate only that the sediment was commonly anoxic; the water column was probably oxic at least intermittently. The presence of articulated phyllocarid arthropods in the black shale seems to offer no reliable clue to water depth. The presence of relatively well articulated phyllocarid remains does not necessarily imply burial in marine settings below storm wave base, nor does it even guarantee that they were buried in exactly the same place where they lived. The inferred habitats of phyllocarids, the presence of abundant coalified plant remains, the lithology, and stratigraphic relationships seem to argue more strongly for a marginal marine setting for the carbonaceous black shale than they do for a deep marine setting.

INTRODUCTION

PHYLLOCARID crustaceans are important components of numerous Carboniferous (Mississippian and Pennsylvanian) biotas, but are rather poorly known from many localities. Although more then a dozen species have been documented from the Carboniferous (Jones and Woodward, 1899; Rolfe, 1969; Copeland, 1967; Copeland and Rolfe, 1978; Factor and Feldmann, 1985; Schram and Horner, 1978; Schram, 1980), few have been documented from complete material. Thus the finding of new articulated specimens can add substantially to our understanding of the paleobiology of these arthropods.

The purposes of this paper are 1, to describe a new species of dithyrocarid archaeostracan, Dithyrocaris rosarius, from the Pennsylvanian age Breathitt Formation of northern Kentucky; 2, to document body and trace fossils found in association with this crustacean; and 3, to interpret the paleoenvironmental conditions under which the phyllocarids and associated animals lived.

GEOGRAPHIC AND STRATIGRAPHIC SETTING

The phyllocarids and other fossils reported here were collected from a recently exposed roadcut along Kentucky Highway 546 ("AA Highway"), approximately 30 km east of Vanceburg, Kentucky (Figure 1; Martino and Rice, 1992). Stratigraphically, they are from a 40-cm-thick carbonaceous black shale within a cyclothemic unit of the Pennsylvanian-age Breathitt Formation (Figure 2). This black shale unit was previously referred to as the AA marine interval (Bennington, 1992). At the time, a deep water origin for the black shale was favored (Bennington, 1992), but new evidence presented here makes the interpretation of depositional environment more equivocal.

At the "AA Highway" locality, a road cut exposes approximately 60 meters of strata through the upper part of the Mississippian Borden Formation and the lower part of the Pennsylvanian Breathitt Formation. A dramatic erosional unconformity separates the two formations. The Breathitt Formation includes, in ascending order, a maroon silty shale that truncates the Borden Formation, and that was interpreted (Bennington, 1992) to be a channel or valley fill. The silty shale is more than 10 meters thick. It is overlain by the Olive Hill flint clay bed. It is important as a regional stratigraphic marker bed, being approximately 3 m thick and bioturbated at the top. The Olive Hill flint clay is truncated by a 3-to-5-m-thick succession of dark gray shale, coal, and flint clay. The base of this succession is erosional and exhibits contorted bedding and slump structures (Martino and Rice, 1992). This series of strata is overlain by a series of inferred tidal channel-fill sequences, 15 m thick, composed primarily of heavily burrowed sandstone. Trace fossils are present near the top of this interval (Bennington, 1992). Above the tidal channel facies is a 3.5-m-thick burrowed muddy sandstone that contains marine fossils such as crinoid columnals and brachiopods. The unit grades upward into a dark gray, muddy, very finely graded, bioturbated sandstone with an increasing frequency of marine fossils (Bennington, 1992).

Above the bioturbated sandstone lies a carbonaceous black shale from which specimens of phyllocarids and other animals documented herein were collected. The unit is about 40 cm thick, moderately silty, fissile, thinly laminated, and dark gray to black. The shale is canneloid. It contains abundant carbonaceous material and burns readily when placed against a lighted match or alcohol lamp. Body and trace fossils are common on only a few of these bedding planes.

The carbonaceous black shale grades upward into a medium gray, silty shale that is capped by a prominent siderite bed. Overlying the siderite is a 2.5-m-thick dark gray siltstone having thin sandy beds. Macrofossils were not observed in this interval. A sandstone bed, 15-cm-thick, overlies the siltstone-sandstone unit and contains obvious root casts (Bennington, 1992).

ASSOCIATED FOSSILS AND PALEOENVIRONMENTAL IMPLICATIONS

In addition to specimens of the new phyllocarid species Dithyrocaris rosarius (Figures 3, 4), the carbonaceous black shale has yielded body fossils of chonetid brachiopods (Figure 5.2, 4), the bivalve Posidonia fracta (Figure 5.2), gastropods, and wood fragments (Figure 5.1). Trace fossils present include Zoophycos (Figure 5.5), tubular fossils resembling Planolites (Figure 5.3, 6), and coprolites (Figure 5.7). The coprolites contain macerated shelly debris, some of which may be fragments of Dithyrocaris exoskeletons.

The carbonaceous black shale has been interpreted as having been deposited during an interval of maximum marine transgression (Bennington, 1992). Bennington cited the following as evidence of his interpretation. An upward-fining of grains from the lower sandy beds to the fine-grained black shale and then to a medium to dark gray silty shale. This was considered to be a single transgressive-to-regressive sediment package; strata were interpreted to have been deposited below storm wave base. Marine fossils (brachiopods, bivalves, gastropods, ostracodes, and corals) were found in the underlying dark gray, muddy, bioturbated sandstone, and phyllocarids, brachiopods, and bivalves were found in the black shale. Lastly, the preservation of delicate phyllocarid remains in the black shale suggested an absence of strong currents, which was interpreted to be evidence of deep water for the unit.

After reexamining the stratigraphy and biota of the carbonaceous black shale unit, a deep water origin seems less certain. Bennington (1992) did not include any trace fossils or wood fragments in his evaluation of the paleoenvironment. Zoophycos (Figure 5.5) is present along several bedding planes in the carbonaceous black shale. Although Zoophycos has commonly been associated with deep (Bjerstedt, 1988) or oxygen-poor (Potter et. al., 1982) deposits in older literature, more recent papers on Devonian or

Pennsylvanian occurrences (Miller, 1991; Kotake, 1994) demonstrate that Zoophycos-producing animals could also live in shallow marine and marginal marine settings. The presence of abundant coalified wood in the black shale, and its canneloid nature, seem to be evidence of a rather shallow, perhaps marginal marine or shallow subtidal, origin for the unit.

Bennington (1992) stated that the presence of phyllocarids in the carbonaceous black shale was evidence of a deep marine origin. However, among the numerous trace fossils in the unit, those that could be attributed to the activity of phyllocarids were not found. Trace fossils produced by phyllocarids have been reported from other locations (Hannibal and Feldmann, 1983; Feldmann et al., 1986), and it is reasonable, by implication, to assume that if D. rosarius were benthic or nektobenthic, it would have left traces in sediment in the environment where it lived. The lack of such traces suggests that the phyllocarids did not live in exactly the same environment as the one in which they were finally deposited. This is especially likely in view of the fact that terrace lines are present only marginally on the exoskeleton. By comparison with trilobites, terrace lines are generally present marginally and ventrally on benthic arthropods (Schmalfuss, 1981) and dorsally on pelagic arthropods (Babcock, 1994b).

The available phyllocarids are moderately to well articulated. It is unlikely that they represent undisturbed corpses, and it is possible that they were transported to their final burial site. Transport could have been accomplished by either currents or by predators or scavengers. The conjugate orientation of exoskeletons on one slab (Figure 3.3) suggests that they were brought into association by storm-induced currents. Transport of phyllocarid remains by storm waves into the black shale environment would not necessarily lead to disarticulation. Recent work (Babcock, 1994a) has shown that arthropod exoskeletons are strongly resistant to disarticulation. Coprolites (Figure 5.7) that may include phyllocarid remains suggest transport by fish into the carbonaceous black shale environment. The damage to the anterior area of most specimens (Figures 3, 4.1, 4.2) could be the result of bites from predators or scavengers.

Repository.-- Specimens reported here have been deposited in the Orton Geological Museum of The Ohio State University, Columbus (OSU).

SYSTEMATIC PALEONTOLOGY

Class MALACOSTRACA Latreille

Subclass PHYLLOCARIDA Packard

Order ARCHAEOSTRACA Claus

Suborder RHINOCARINA Clarke in Zittel

Family RHINOCARIDIDAE Hall and Clarke, 1888

Genus DITHYROCARIS Scouler in Portlock, 1843

Type species.--Argas testudineus Scouler, 1835, by subsequent designation (Roemer in Bronn and Roemer, 1854).

Remarks.-- The generic concept of Rolfe (1969: p. R321) is followed here. Rolfe (1969) noted that the distinction between some genera in the family Rhinocarididae is difficult, and that the family is in need of revision. Such a revision has yet to be published. In all respects, the new specimens of dithyrocarid reported here conform to the diagnosis of Dithyrocaris (Rolfe, 1969). However, the new material does not closely resemble any described species from other genera in the Rhinocarididae, and there is little chance of confusing this form with others that may be closely related.

DITHYROCARIS ROSARIUS n. sp.

Figures 3,4, Table 1

Etymology.--From Latin, rosarius, made of roses (rosary); alluding to the string of bead-like nodes on each furca.

Holotype.--Articulated exoskeleton, OSU 46349.

Other material.--More then 20 specimens ranging from individual sclerites to articulated exoskeletons.

Diagnosis.--Dithyrocaris having moderately wide carapace; lacking carapace horn anteriorly; posteroventral spine small; doublure width increasing backward; telson narrow, shorter then furca; furca narrow, having row of strong bead-like nodes on inside edge.

Description.-- Carapace moderately wide for genus, strongly curved anteroventrally, gently curved posterioventrally, lacking carapace horn, having moderately small posteroventral spine; anterior tubercle present; mesolateral carina strong, consisting of series of imbricate chevrons delineated by terrace lines and terminating in small blunt points; doublure narrow anteriorly, width increasing slightly posteriorly, covered with closely spaced, oblique, posteriorly imbricating, terraced ridges; axial plate narrow, extending into short posteromedial spine; dorsal surface covered with fine ridges arranged in reticulate pattern; doublure covered with posterolaterally directed terrace lines. Abdomen containing 7 somites, anterior 3 somites lightly sclerotized, posterior 4 somites more heavily sclerotized; posterior 4 somites covered with widely spaced, posterolaterally directed terrace lines. Telson long for genus but much shorter than furca; elongate subtriangular, narrow, having strong longitudinal carina dorsally. Furca long for genus; narrow, having several longitudinal ridges and row of strong bead-like nodes present on interior edge of side. Mandibles robust, heavily sclerotized, having large palp foramen, asymmetrical on molar surface; right mandible having about 6 cusps along length of molar surface, left mandible cuspate anteriorly and apparently smooth behind on molar surface.

Remarks.-- The specimens described here have been crushed in carbonaceous black shale but still retain evidence of important morphological characters. Dithyrocaris rosarius n. sp. has the longest and narrowest telson and furcae described in the genus. The furcae, which are much longer than the telson, also exhibit the strongest known row of nodes along the inside edge in the genus (Figures 4.4,6). The nodes seem to be attachment points for setal hairs.

Of the described species, D. rosarius differs from D. tricornis, D. glabra, D. granulata, D. scouleri, D. quinni, and D. rolfei, in having a wider carapace. Dithyrocaris rosarius also differs from D. glabra, D. granulata, D. paradoxides, and D. quinni in not having a carapace horn. Dithyrocaris rosarius has a shorter posteroventral spine than does D. tricornis, D. scouleri, D. colei, D. orbicularis, and D. paradoxides.

Dithyrocaris rosarius is most similar to D. insignis. Both have one mesolateral carina, and a medial dorsal plate that protrudes beyond the carapace margin. Although both species share a reticulate pattern of ornamentation, the spacing of the pattern is different, with D. insignis exhibiting a wider spacing then that found in D. rosarius. The dorsal plate and the mesolateral carina are narrower in D. rosarius than they are in D. insignis. Dithyrocaris insignis also lacks the strong nodes found on the furca of D. rosarius.

Dithyrocaris venosa, which is known from tail pieces collected in Illinois is approximately the same size as D. rosarius. The ornamentation of the tails appears to be different, however. The penultimate abdominal segment in D. venosa has terrace lines that run laterally, rather then longitudinally as in D. rosarius. Dithyrocaris venosa also appears to lack the strong nodes on the furca.

The other species collected from North America also show pronounced differences from D. rosarius. Dithyrocaris carbonaria is known from tail pieces collected in Illinois. The telson and furcae are both stouter and shorter than in D. rosarius, and the furca lack strong nodes. Specimens from Ohio referred to as Dithyrocaris sp. show a telson and furcae that are of approximately equal length. Strong nodes are not present on the furcae. A species left in open nomenclature from the Canadian Yukon is much larger then D. rosarius. Little else can be determined from photographs of the fragmentary illustrated specimen.

Table 1. Measurements of fossils of Dithyrocaris rosarius n. sp.

Specimen #	Carapace Length (exclusive of posteroventral spine)	Length of Posteroventral spine	Maximum carapace width
OSU 46349	34mm	3mm	17mm
OSU 46350 A	41mm	3mm	21mm
OSU 46350 B	38mm	2mm	18mm
OSU 46350 C	36mm	1.5mm	17mm

* Holotype

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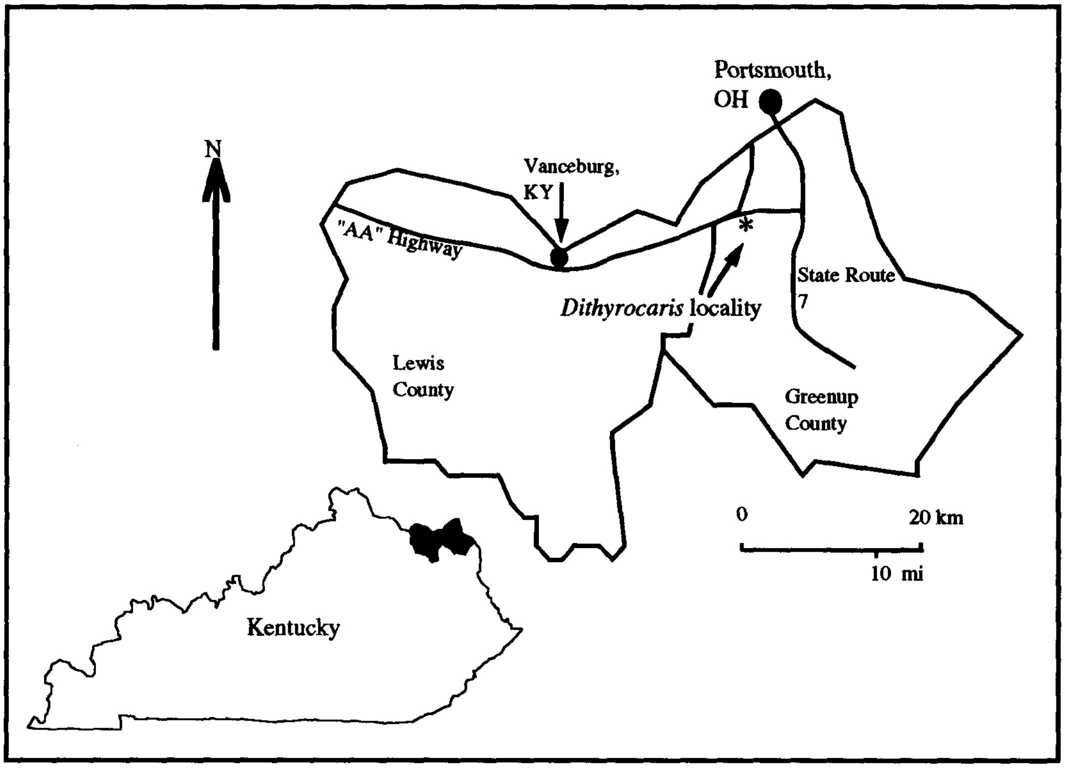


Figure 1--Location map showing site where Dithyrocaris rosarius n. sp. and associated fauna were collected.

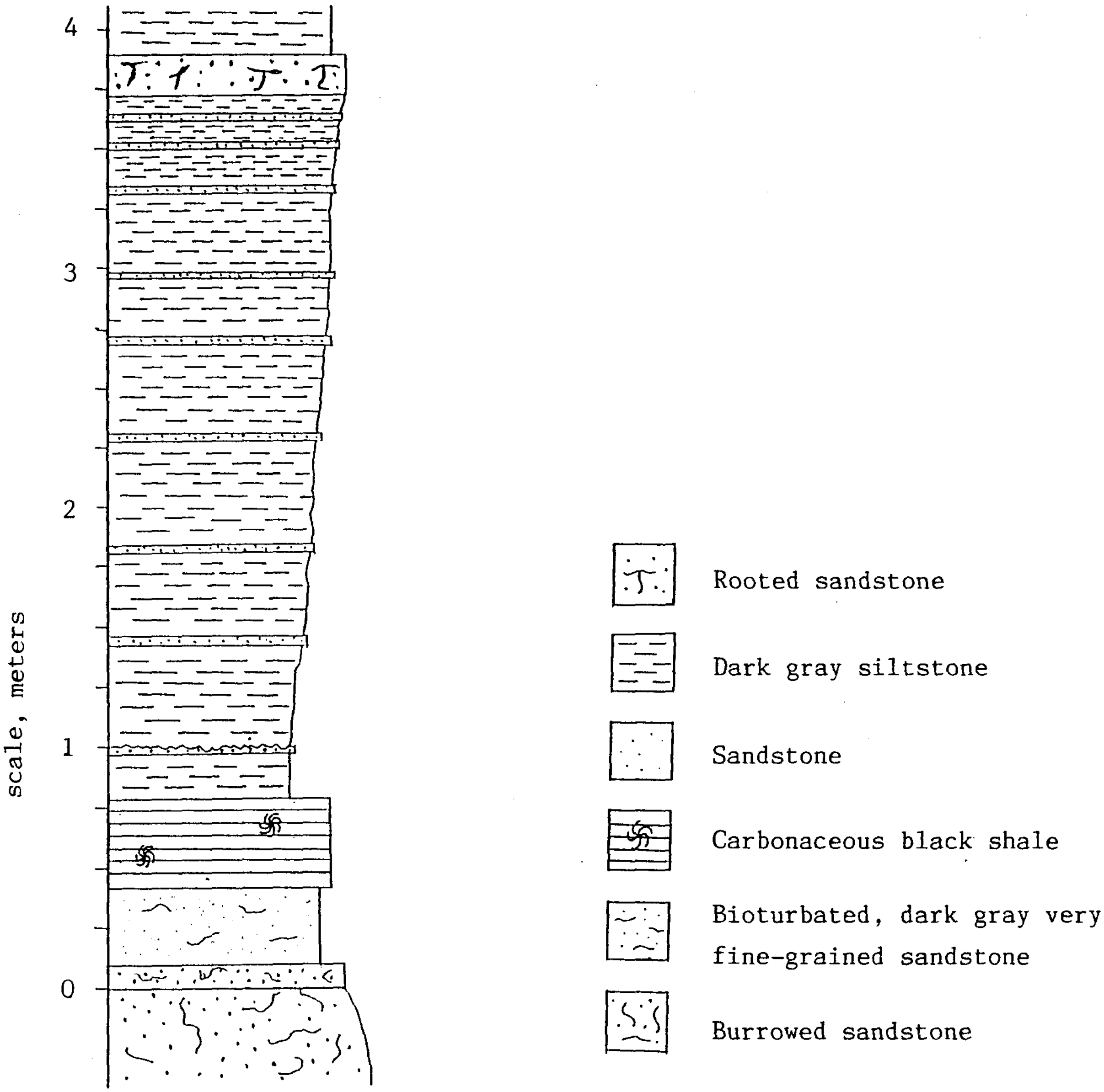
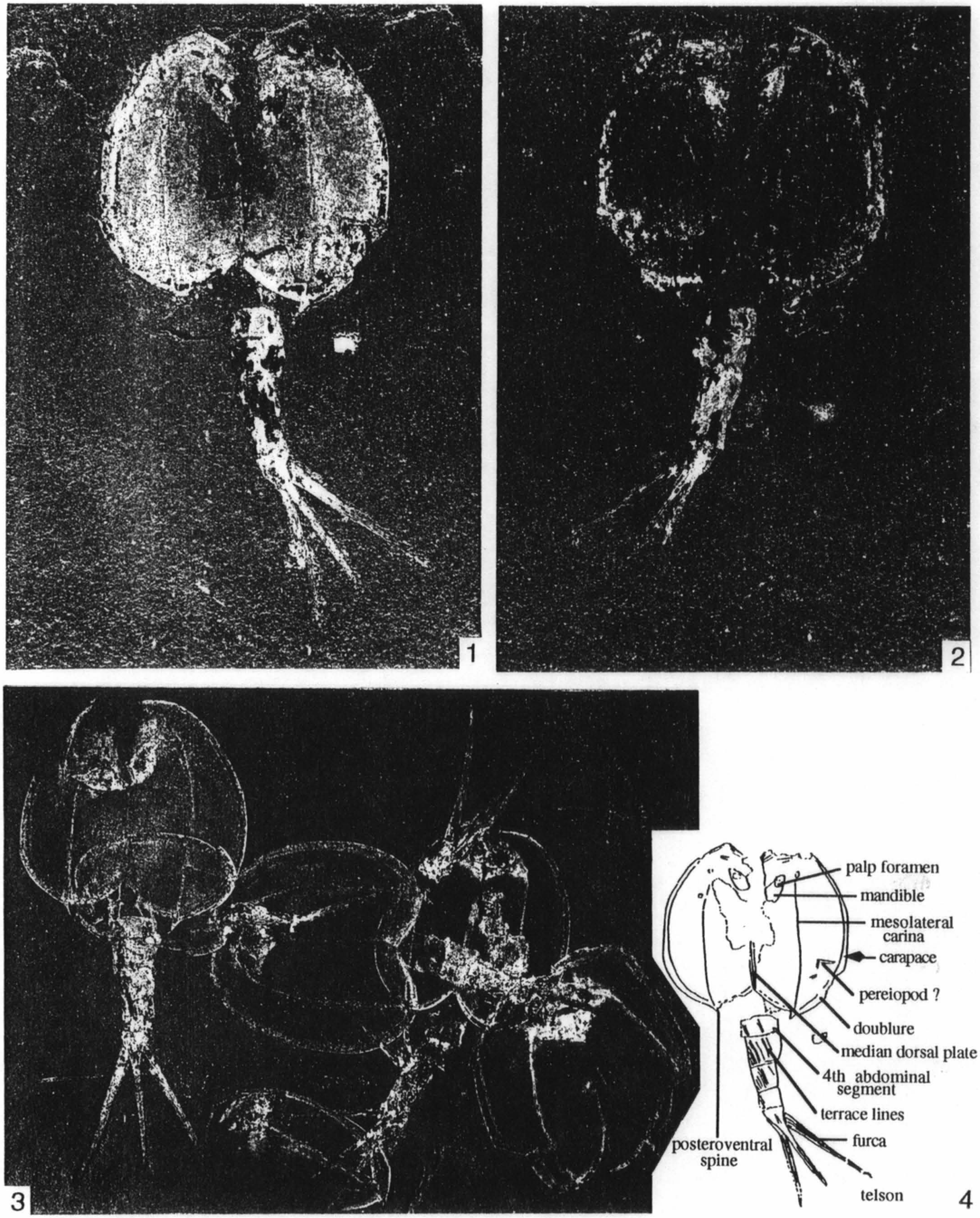


Figure 2--Detail of section where Dithyrocarus rosarius n. sp. and associated fauna were collected (modified from Bennington, 1992).

FIGURE 3--*Dithyrocaris rosarius* n. sp. from the Breathitt Formation northern Kentucky (Pennsylvanian). *1*, Holotype, part; OSU 46349A; ×2. *2*, Holotype, counterpart; OSU 46349B; ×2. *3*, Slab containing remains of at least six *D. rosarius* specimens; OSU 46350A-F; ×1. *4*, Explanatory diagram of part of *D. rosarius*, holotype (see Figure 3.1); OSU 46349A; ×1.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palp foramen
mandible
mesolateral carina
carapace
pereiopod ?
doublure
median dorsal plate
4th abdominal segment
terrace lines
furca
posteroventral spine
telson
4

FIGURE 4--Dithyrocaris rosarius n. sp. from the Breathitt Formation northern Kentucky (Pennsylvanian). 1, Carapace and tail section, OSU 00000; ×1. 2, Two incomplete specimens; OSU 00000; ×1. 3, Enlargement of carapace of holotype, showing ornamentation and terrace lines along mesolateral ridge; OSU 46349A; ×5. 4, Enlargement of tail region of holotype, showing strong nodes on the furcae; OSU 46349A; ×2. 5, Enlargement of specimen in Figure 4.2, showing reticulate pattern of ornamentation; OSU 00000; ×10. 6, Tail and abdominal region of two specimens; OSU 00000; ×1.

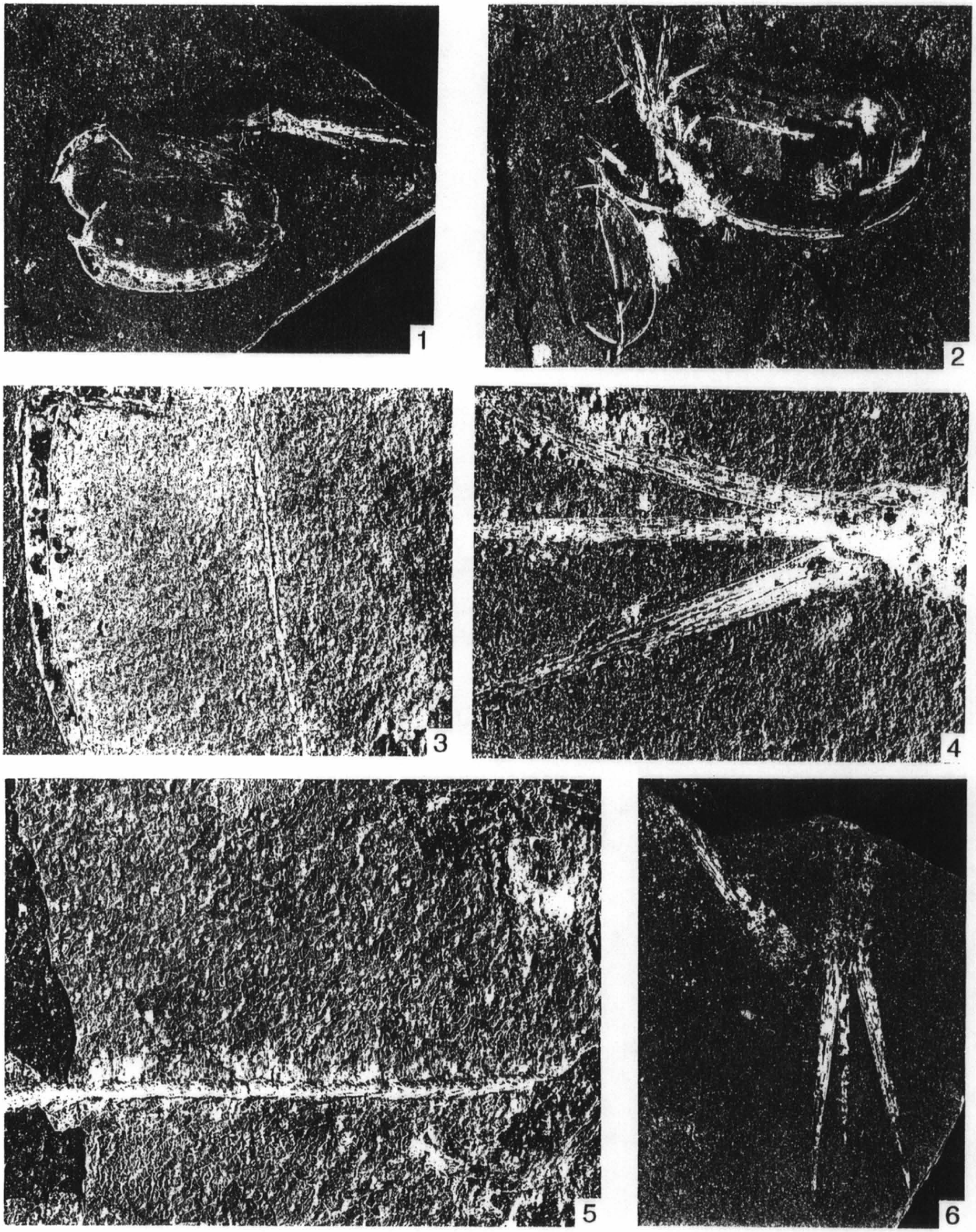
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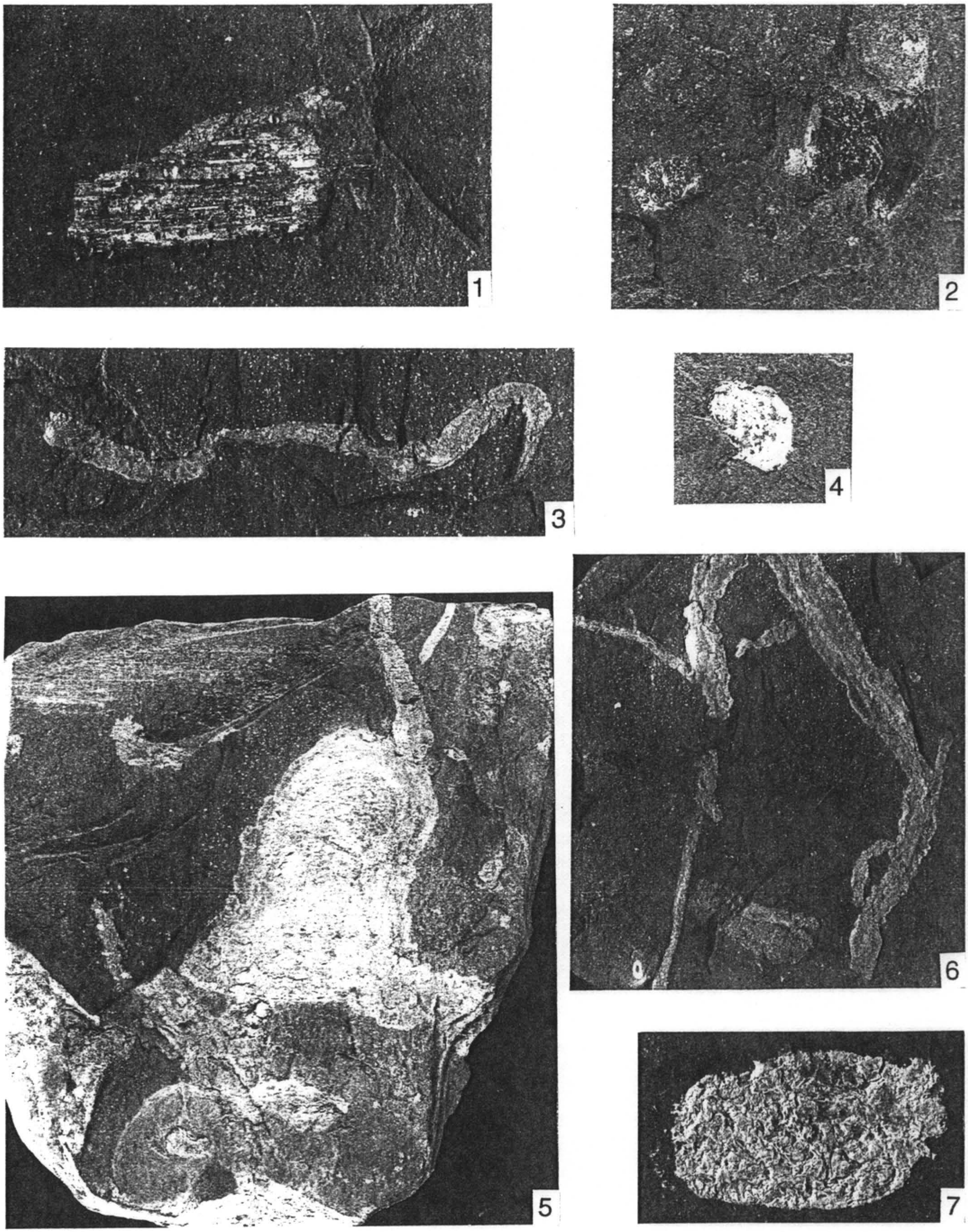
FIGURE 5--Associated body and trace fossils found with D. rosarius n. sp. from the Breathitt Formation northern Kentucky (Pennsylvanian). 1, Coalified wood fragment; OSU 00000; ×2. 2, Posidonia fracta, common bivalve and chonetid brachiopod; OSU 00000; ×1.5. 3, Tubular trace fossil resembling Planolites; OSU 00000; ×1. 4,Chonetid brachiopod; ×1.5. 5, Zoophycos, trace fossil; OSU 00000; ×1. 6, Tubular trace fossil resembling Planolites; OSU 00000; ×1.5. 7, Coprolite, showing possible D. rosarius fragments; OSU 00000; ×5.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